Claims

[c1] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,

the filter factors have a symmetrical sequence and values of the filter factors are set so that a sum of the sequence is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs.

[c2] The digital filter according to claim 1, the sequence of filter factors is composed of ratios of –1, 0, 9, 16, 9, 0, and –1.

[c3] The digital filter, comprising:

the digital filter of claim 2 is cascaded in a plurality of stages.

[c4] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,

the filter factors have a symmetrical sequence and values are set so that a sum of the sequence is zero and a sum

of every other terms is equal to a sum of the other every other terms with opposite signs.

[c5]   The digital filter according to claim 4, the sequence of filter factors is composed of ratios of 1, 0, –9, 16, –9, 0, and 1.

[c6]   The digital filter, comprising:
the digital filter of claim 5 is cascaded in a plurality of stages.

[c7]   The digital filter, comprising:
the digital filter of claim 2 and the digital filter of claim 5 are cascaded.

[c8]   A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on first filter factors having a symmetrical sequence in which values are set so that a sum is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs, and second filter factors are provided as filter factors for the signals of the taps, the second filter factors being obtained by reversing signs of values other than a median of the sequence of the first filter factors while

causing absolute values of the sequence to remain the same.

[c9] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on first filter factors having a symmetrical sequence in which values are set so that a sum is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs, and second filter factors are provided as filter factors for the signals of the taps, the second filter factors being obtained by reversing signs of values other than a median of the sequence of the first filter factors while absolute values of the sequence is caused to remain the same, and subtracting the median of the sequence from a reference value.

[c10] The digital filter according to claim 8, the first filter factors are composed of a sequence obtained by cascading a basic filter in one or more stages, the basic filter constituted using, as filter factors, a sequence composed of ratios of −1, 0, 9, 16, 9, 0, and −1.

[c11] The digital filter according to claim 9, the first filter factors are composed of a sequence obtained by cascading

a basic filter in one or more stages, the basic filter constituted using, as filter factors, a sequence composed of ratios of –1, 0, 9, 16, 9, 0, and –1.

[c12] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on first filter factors having a symmetrical sequence in which values are set so that a sum is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs, and second filter factors are provided as filter factors for the signals of the taps, the second filter factors having a sequence in which values are set so that sums of the first filter factors and the second filter factors serve as reference values.

[c13] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on second filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, and first filter factors are provided as filter

factors for the signals of the taps, the first filter factors being obtained by reversing signs of values other than a median of the sequence of the second filter factors while causing absolute values of the sequence to remain the same.

[c14] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on second filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, and first filter factors are provided as filter factors for the signals of the taps, the first filter factors being obtained by reversing signs of values other than a median of the sequence of the second filter factors while causing absolute values of the sequence to remain the same, and subtracting the median of the sequence from a reference value.

[c15] The digital filter according to claim 13, the second filter factors are composed of a sequence obtained by cascading a basic filter in one or more stages, the basic filter constituted using, as filter factors, a sequence composed of ratios of 1, 0, −9, 16, −9, 0, and 1.

[c16] The digital filter according to claim 14, the second filter factors are composed of a sequence obtained by cascading a basic filter in one or more stages, the basic filter constituted using, as filter factors, a sequence composed of ratios of 1, 0, –9, 16, –9, 0, and 1.

[c17] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on second filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, and first filter factors are provided as filter factors for the signals of the taps, the first filter factors having a sequence in which values are set so that sums of the first filter factors and the second filter factors serve as reference values.

[c18] A digital filter, comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on first filter factors having a symmetrical sequence in which values are set so that a

sum is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs, and second filter factors are provided as filter factors for the signals of the taps, the second filter factors being obtained by converting the sequence of the first filter factors and setting values so that a sum of the converted sequence is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs in the converted sequence.

[c19] A digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output,
the filter is designed based on second filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, and first filter factors are provided as filter factors for the signals of the taps, the first filter factors being obtained by converting the sequence of the second filter factors and setting values so that a sum of the converted sequence is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs in the converted sequence.

[c20]   A method of designing a digital filter, the digital filter
         comprising a tapped delay line made up of a plurality of
         delay units, the digital filter multiplying signals of taps
         by given filter factors and then performing addition and
         output, the method comprises:
         determining filter factors for the signals of the taps by
         reversing signs of values other than a median of the se-
         quence of basic filter factors while causing absolute val-
         ues of the sequence to remain the same based on the
         basic filter factors having a symmetrical sequence in
         which values are set so that a sum is not zero and a sum
         of every other terms is equal to a sum of the other every
         other terms with the same signs.

[c21]   A method of designing a digital filter, the digital filter
         comprising a tapped delay line made up of a plurality of
         delay units, the digital filter multiplying signals of taps
         by given filter factors and then performing addition and
         output, the method comprises:
         determining filter factors for the signals of the taps by
         reversing signs of values other than a median of the se-
         quence of basic filter factors while causing absolute val-
         ues of the sequence to remain the same, and subtracting
         the median of the sequence from a reference value,
         based on the basic filter factors having a symmetrical
         sequence in which values are set so that a sum is not

zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs.

[c22] The method of designing the digital filter according to claim 20, the basic filter factors are composed of a sequence of ratios of –1, 0, 9, 16, 9, 0, and –1.

[c23] The method of designing the digital filter according to claim 21, the basic filter factors are composed of a sequence of ratios of –1, 0, 9, 16, 9, 0, and –1.

[c24] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output, the method comprises:
determining filter factors for the signals of the taps by reversing signs of values other than a median of the sequence of basic filter factors while causing absolute values of the sequence to remain the same based on the basic filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs.

[c25] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of

delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output, the method comprises:

determining filter factors for the signals of the taps by reversing signs of values other than a median of a sequence of basic filter factors while causing absolute values of the sequence to remain the same, and subtracting the median of the sequence from a reference value, based on the basic filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs.

[c26] The method of designing the digital filter according to claim 24, the basic filter factors are composed of a sequence of ratios of 1, 0, −9, 16, −9, 0, and 1.

[c27] The method of designing the digital filter according to claim 25, the basic filter factors are composed of a sequence of ratios of 1, 0, −9, 16, −9, 0, and 1.

[c28] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output, the method comprises:

determining filter factors for the signals of the taps by

converting the sequence of basic filter factors and set-
ting values so that a sum of the converted sequence is
zero and a sum of every other terms is equal to a sum of
the other every other terms with opposite signs in the
converted sequence, based on the basic filter factors
having a symmetrical sequence in which values are set
so that a sum is not zero and a sum of every other terms
is equal to a sum of the other every other terms with the
same signs.

[c29] A method of designing a digital filter, the digital filter
comprising a tapped delay line made up of a plurality of
delay units, the digital filter multiplying signals of taps
by given filter factors and then performing addition and
output, the method comprises:
determining filter factors for the signals of the taps by
converting the sequence of basic filter factors and set-
ting values so that a sum of the converted sequence is
not zero and a sum of every other terms is equal to a
sum of the other every other terms with the same signs
in the converted sequence, based on the basic filter fac-
tors having a symmetrical sequence in which values are
set so that a sum is zero and a sum of every other terms
is equal to a sum of the other every other terms with op-
posite signs.

[c30]   A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output, the method comprises:
cascading a basic filter inn stages (n = 1), the basic filter being constituted using basic filter factors having a symmetrical sequence in which values are set so that a sum is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs, and determining, as filter factors for the signals of the taps, nth-order filter factors obtained thus.

[c31]   The method of designing the digital filter according to claim 30, signs of values other than a median of a sequence of the nth-order filter factors are reversed while causing absolute values of the sequence to remain the same, and transfer filter factors obtained thus are determined as filter factors for the signals of the taps.

[c32]   The method of designing the digital filter according to claim 30, signs of values other than a median of a sequence of the nth-order filter factors are reversed while causing absolute values of the sequence to remain the same, the median of the sequence is subtracted from a reference value, and transfer filter factors obtained thus are determined as filter factors for the signals of the

taps.

[c33] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output, the method comprises:
cascading a basic filter in n stages (n = 1), the basic filter being constituted using basic filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, and determining, as filter factors for the signals of the taps, nth-order filter factors obtained thus.

[c34] The method of designing the digital filter according to claim 33, signs of values other than a median of a sequence of the nth-order filter factors are reversed while causing absolute values of the sequence to remain the same, and transfer filter factors obtained thus are determined as filter factors for the signals of the taps.

[c35] The method of designing the digital filter according to claim 33, signs of values other than a median of a sequence of the nth-order filter factors are reversed while causing absolute values of the sequence to remain the same, the median of the sequence is subtracted from a

reference value, and transfer filter factors obtained thus are determined as filter factors for the signals of the taps.

[c36] The method of designing the digital filter according to claim 30, a pass frequency band of the filter is shifted by changing a delay rate of the delay unit.

[c37] The method of designing the digital filter according to claim 33, a pass frequency band of the filter is shifted by changing a delay rate of the delay unit.

[c38] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps by given filter factors and then performing addition and output, the method comprises:
shifting a pass frequency band of the filter by changing a delay rate of the delay unit in a basic filter constituted using basic filter factors having a symmetrical sequence in which values are set so that a sum is not zero and a sum of every other terms is equal to a sum of the other every other terms with the same signs.

[c39] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying signals of taps

by given filter factors and then performing addition and output, the method comprises:

shifting a pass frequency band of the filter by changing a delay rate of the delay unit in a basic filter constituted using basic filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs.

[c40] The method of designing a digital filter, comprising:
a filter using the filter factors obtained by the designing method according to claim 30 is cascaded in m stages (m = 1), so that a pass frequency band of the filter is adjusted.

[c41] The method of designing a digital filter, comprising:
a filter using the filter factors obtained by the designing method according to claim 33 is cascaded in m stages (m = 1), so that a pass frequency band of the filter is adjusted.

[c42] The method of designing a digital filter, comprising:
a filter using the filter factors obtained by the designing method according to claim 38 is cascaded in m stages (m = 1), so that a pass frequency band of the filter is adjusted.

[c43] The method of designing a digital filter, comprising:
a filter using the filter factors obtained by the designing
method according to claim 39 is cascaded in m stages
(m = 1), so that a pass frequency band of the filter is ad-
justed.

[c44] The method of designing a digital filter, comprising:
a filter using the filter factors obtained by the designing
methods according to claims 30, 33, 38, and 39 and a
filter using the filter factors obtained by the designing
method according to any other one of claims 30, 33, 38,
and 39 are arbitrarily cascaded, so that a pass frequency
band of the filter is adjusted.

[c45] A method of designing a digital filter, the digital filter
comprising a tapped delay line made up of a plurality of
delay units, the digital filter multiplying signals of taps
by given filter factors and then performing addition and
output, the method comprises:
cascading a first basic filter inn stages (n = 1), the first
basic filter being constituted using first basic filter fac-
tors having a symmetrical sequence in which values are
set so that a sum is not zero and a sum of every other
terms is equal to a sum of the other every other terms
with the same signs, and shifting a pass frequency band
of the filter by changing a delay rate of the delay unit, so
that nth-order filter factors are obtained;

cascading a second basic filter in m stages (m = 1), the second basic filter being constituted using second basic filter factors having a symmetrical sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, and shifting a pass frequency band of the filter by changing a delay rate of the delay unit, so that mth-order filter factors are obtained; cascading the filter using the nth-order filter factors and the filter using the mth-order filter factors; and reversing signs of values other than a median of the sequence of the filter factors obtained by the cascade connection while causing absolute values of the sequence to remain the same, and subtracting the median of the sequence from a reference value, so that transfer filter factors obtained thus are determined as filter factors for the signals of the taps.

[c46] A method of designing a digital filter, the digital filter comprising a tapped delay line made up of a plurality of delay units, the digital filter multiplying the signals of taps by given filter factors and then performing addition and output, the method comprises:
based on first filter factors having a symmetrical sequence in which values are set so that a sum is not zero and a sum of every other terms is equal to a sum of the

other every other terms with the same signs or having a sequence in which values are set so that a sum is zero and a sum of every other terms is equal to a sum of the other every other terms with opposite signs, determining second filter factors obtained when a basic filter constituted using the first filter factors is cascaded in a plurality of stages, the second filter factors are obtained when the basic filter is cascaded for the number of stages where a frequency changing with the number of cascaded stages exceeds a target frequency;

reversing signs of values other than a median of a sequence of the second filter factors while causing the absolute values of the sequence to remain the same based on the determined second filter factors, and subtracting the median of the sequence from a reference value, so that transfer filter factors are obtained;

determining third filter factors obtained when an interim product filter constituted using the transfer filter factors is cascaded in a plurality of stages based on the transfer filter factors, the third filter factors are obtained when the interim product filter is cascaded for the number of stages where a frequency changing with the number of cascaded stages exceeds the target frequency;

similarly determining, based on the determined third filter factors, transfer factors and filter factors repeatedly, the filter factors being obtained when an interim product

filter constituted using the transfer filter factors is cascaded, and reducing an error between a frequency obtained thus and the target frequency to determine final filter factors.